Survey of New Zealand Hydrologists on Information Needs

Gerard William[1]

Mark W. Milke[1, 2]

John F. Raffensperger[1]

1 University of Canterbury, Private Bag 4800, Christchurch, New Zealand

2 Corresponding author: mark.milke@canterbury.ac.nz

Submitted to Journal of Hydrology (New Zealand)--10 July 2008

Resubmitted—16 December 2008

Abstract

New Zealand's hydrologists were surveyed to determine what information they believe is lacking and what information they believe is important for more effective management and allocation of New Zealand's freshwater supply. Two research questions and five qualitative questions related to information needs and water policy were administered to 79 hydrologists through an online survey. The survey identified four factors as both important and lacking to hydrologists: (1) representative models, (2) data for more-advanced models, (3) information on interaction of water with other variables, and (4) information on sustainability of water resources. Five additional qualitative questions supported these findings and identified further areas of concern.

Keywords

On-line questionnaire; hydrologists.

Introduction

This paper presents the results of a survey of New Zealand hydrological scientists. The survey asked the scientists which hydrology data was both important and lacking. New Zealand's problems of water allocation and quality are becoming increasingly serious, yet solutions continue to seem just out of reach. These problems vary by magnitude and concern over the different regions of the country (White and Rosen, 2001; Davies-Colley and Wilcock, 2004; Richmond et al, 2004; Woods and Howard-Williams, 2004; Env Waikato 2008). Addressing these problems requires good water policy. Water policy is a broader area than hydrology, and requires a broader range of expertise. However, good policy requires good hydrological expertise. Further, to make scientifically robust decision on water management, hydrologists require various types of information. Often, lack of data impedes measuring and forecasting abilities, and small mistakes in calculations can lead to drastically mistaken results (Baca, 1999), which can in turn lead to mis-evaluation. It is of interest to know what data are important to hydrologists, and what data they lack to solve New Zealand's water quality and quantity problems. To our knowledge, only one survey has been done of NZ hydrologists (Lowry et al, 2003), and this was to staff at regional councils.

The New Zealand Careers Services website (http://www.careers.govt.nz) indicates that there were 2,934 hydrologists in New Zealand in 2001. Hydrologists (including hydrogeologists) are employed by Crown Research Institutes (CRIs), regional councils, territorial authorities, and universities. Other hydrologists are either self-employed, work for private firms, are consultants or are part of community interests groups. Hydrologists are employed by all regions of New Zealand, with the most representation in Auckland (38%), Wellington (13%) and Canterbury (11%) (CareerServices, 2008).

Individual hydrologists can have expertise in specific types of water, such as in freshwater, atmospheric water, lake water, soil water, river water, or groundwater. In addition, they are often experts in certain disciplines related to one or more types of water, such as chemistry, geology, ecology, fluid flow, monitoring, simulation, or analysis. Our survey tried to allow for the diversity of information needs.

Methodology

Questionnaire design

From a literature search, we identified preliminary factors related to the lack of information. If something was judged of interest to the research questions, it was listed as a factor. This process uncovered fifty potential factors. We then had to design questions to elicit the desired information, and test the questionnaire to refine it.

Typically, survey designers choose between quantitative and qualitative questions. Quantitative questions are answered as or easily recorded as numerical values. Qualitative questions, which are usually projective in order not to be leading, are answered in text. Quantitative and qualitative questions each have advantages (Hair et al., 2003; Lewin, 2005; Taylor and Bogdan, 1998; Saunders, Lewis and Thornhill, 2007). Quantitative questions allow better validation of facts and provide structure to the research. Such methods are particularly useful for larger samples that yield statistical and descriptive information. A quantitative method will have greater potential to be reproduced, be easier to administer, and

be more readily recorded. Qualitative methods can yield descriptive data, and to identify new ideas and insights for future research.

Both forms have inherent limitations. It is difficult to develop accurate instruments for quantitative methods, and the methods lack depth and have potentially lower response rates (Hair et al., 2003). Qualitative methods lack generalisability and reliability (Hair et al., 2003). Using a combination of both methods can emphasise the advantages of each, while reducing their disadvantages. We therefore chose to use both types.

The first two survey questions used quantitative scales: a six point scale for the first, and a five point scale for the second one. Both questions gave an option to respond ‘not applicable’. To prevent any observer-expectancy effects (Gray, 2002), factors were listed as short phrases instead of statements.

Five optional qualitative questions allowed open-ended answers, to seek free-flowing responses that cannot be predicted by the researcher (Brace, 2004). To encourage full responses, the five questions included the phrase, “please briefly elaborate”.

Questionnaire refinement

A draft version of the questionnaire was trialled with four academics from the Water Study Group at the University of Canterbury. Trialling questionnaires is good practice in survey development (Brace, 2004; Punch, 2003). The feedback was taken into account, and the improved questionnaire was then further trialled with five senior practising hydrologists for further critique. The hydrologists’ feedback resulted in a further refined questionnaire that

was suitable for sending out to the subject group. Based on this feedback, we reduced the fifty factors to twenty-four. The questions in the final questionnaire are shown in Table 1.

[Table 1 about here]

In addition, background questions asked about the respondent's hydrological experience (in years), employer, region, areas of expertise, and main issues within the respondent's region.

Although there were no identifiable ethical issues such as deception, manipulation of respondents, or seeking of sensitive personal information, human ethics approval was sought through the University of Canterbury's ethics committee prior to any contact with respondents. As a result, respondents were promised confidentiality arising from use of data sought from them.

Subjects and implementation

The selected survey population was New Zealand hydrologists. Specifically, the New Zealand Hydrological Society was targeted, as it is the body with the largest membership of people working in hydrology and other water-related fields in New Zealand. The Society has a mailing list of 351 members, comprising employees of CRIs and regional councils, academics, consultants, students and overseas members, and a letter inviting participation was sent to all. Reminder letters were sent one week later to increase response rates. 79 members started the survey (22.5% response rate**)**, and 60 completed surveys were received (75.9% completion rate). At the end of the questionnaire, respondents were requested to rate the

survey itself. The rating was 5.09 (standard deviation of 1.96) which corresponded to 'adequate' on a scale of zero to ten.

Self-administered online surveys have advantages over conventional surveys (Hair et al., 2003; Brace, 2004): they allow the respondent to complete the survey in their own time; they eliminate the need to encode data from paper survey forms; they are less likely to generate errors; they have speedier data collection methods; they have higher response rates; and the resultant data are easier to analyse. However, online surveys can suffer from usability problems, such as script problems which prevent completion, as did ours. The questionnaire was administered online using the Survey Monkey service (http://www.surveymonkey.com), through a proxy website which provided a short, easy-to-remember link: www.hydrologyysurvey.co.nz.

Analysis of results

Quantitative data were then treated and analysed with one-sample t-tests (Rodeghier, 1996; Carver and Nash, 2006) through the Statistical Package for Social Sciences (SPSS) software. Qualitative responses were analysed and coded into themes (Taylor et al., 1998).

Results

Characteristics of respondents

Table 2 shows that respondents have a wide variety of employment situations. Regional representation was not evenly distributed (Table 3). The majority of respondents work in New Zealand's five main economic centres of Canterbury, Waikato, Otago, Wellington, and Auckland. There was no representation from Marlborough.

Table 2 about here Table 3 about here

Note that 78 respondents completed the employer type, while 74 respondents completed the region question. Sixty respondents completed all the questions. We have reported all results, rather than attempt to disregard some.

Figure 1 shows that respondents had many areas of expertise, and the only one unrepresented was eco-toxicology. The most common areas of expertise were surface water, catchment hydrology, river water, fresh water, water allocation, water quantity research, water quantity monitoring, and groundwater.

[Figure 1 about here]

The main issues were identified for each region. The most salient ones are listed alongside each region in Table 4 below. Identified issues with one or fewer selections were excluded from the analysis.

[Table 4 about here**]**

While Table 4 shows support for the notion that issues differ across the regions of the country, core issues such as water quality, water quantity, water management and water allocation were identified by all regions.

A high proportion (47.4%) of respondents had more than 20 years of hydrology experience. This was followed by hydrologists with 1–5 years (20.5%), 11–15 years (12.8%), 6–10 years (10.3%) and 16–20 years (9%) of experience.

Research questions

This section reports detailed results for each of the seven key research questions.

1. **Indicate the extent to which you lack information on the following factors as relevant to your work (0= low lack of information, 5 = high lack of information)**

The mean scores for all 24 factors are shown in Table 5. Visual analysis of histograms revealed a normal-like distribution of the scores for all factors. Lack of normality for all factors was tested and not found to be statistically significant. A one-sample t-test was conducted on each of the 24 factors. The t-test was for a difference from the mean of '2.5', which corresponded to a 'medium lack' of data. The most widely used measure of scale consistency is the Cronbach's alpha, with a generally accepted lower threshold of 0.60 indicating reliability for exploratory research (Hair et al., 2003) The Cronbach's alpha coefficient for the 24 factors was 0.901, which indicated good reliability.

[Table 5 about here]

We identified factors that hydrologists reported as lacking, by statistically testing whether respondents as a group assigned each factor an answer statistically close to a mean of 3 (medium lack) or more (medium-high and high lack). The five factors identified as lacking are as follows:

- representative models,
- data for more advanced models (e.g., those requiring the use of GIS technology),
- climate change data,
- information on interaction of water with other variables (e.g., groundwater–surface water interactions), and
- information on sustainability of water resources.

2. **How important do you feel the following factors are to your work towards water management? (0 = low importance, 6 = extremely high importance)**

A similar technique to that used in the first research question was employed to test the 24 factors for this question. Statistical normality was found for the 24 factors. The new test value was 4, which corresponds to 'medium-high importance'. The results are shown in Table 6. The Cronbach's alpha coefficient was 0.817 for the 24 factors, which indicates good reliability of the factors.

Factors that were not significantly different from a mean of 3 (medium-high importance), or had a mean that was higher than 3 were rated as 'important' factors. The four most important factors are as follows, in descending order of importance:

- Good monitoring devices
- High measurement accuracy
- Sustainability of water resources
- Water interactions (e.g., groundwater-surface water interactions)

[Table 6 about here]

3. **What kind of models do you currently use?**

Respondents typically used models for simulations, forecasts and predictions. The terms provided to describe the models used were hydraulics, groundwater, flood forecasting, land

use changes, contaminant transport, catchment hydrology, river and groundwater flow, ecological systems and habitats, surface–groundwater interactions, soil moisture, hydrogeology, and river basin modelling.

The modelling tools used are identified by frequency as follows:

MODFLOW, Visual MODFLOW	5
HEC-HMS, HEC, HEC-RAS	4
Microsoft Excel spreadsheets	3
TopNet	3
FEMFLOW	2
Tiseda PSIM	2

Identified just once were the following: DHI, DHSVM (Distributed Hydrology Soil & Vegetation Model), GIS, GMS, EarthVision, Eigen, Hydrol, MIKE-BASIN, NAM, NPLAS, RIVER2D, RHYHABSIM, RORB, Surfer 7, TOPMODEL, TP61, TP108, Watyield, WAIORA, WBNM, and WEPP.

Some hydrologists mentioned that they faced a lack of data (e.g., “There is a severe lack of research data on Southern Alps rainfall”), while others emphasised the lack of funding (e.g., “… we do not have the resources to move into this area at the moment but do see its potential benefits”).

4. Do you find anything lacking in these models?

While some respondents found little lacking in their models, most respondents identified several key concerns. The main factors lacking from models were reliability, validity and

verification (e.g., violations of assumptions, testing models empirically), available data (such as rainfall data in remote areas, groundwater–surface water interactions), and ease of calibration of models for New Zealand conditions. In addition, respondents had problems with technical issues associated with models (e.g., the interface, technical assistance), and the costs involved with purchasing data (especially for smaller users).

One respondent commented on the importance of good modelling practice despite its limitations: "Validation of modelling output is rare… Groundwater models, for example, can only be validated by stressing the resource, which amounts often to over-allocation."

5. **What sort of data would you need for the models that you would prefer to use in the future?**

Respondents expressed the need for more accurate and reliable data, for model calibration data, and for data that were spatially distributed so as to accurately represent New Zealand. A common concern was the unavailability of data from different New Zealand regions, quoting from questionnairies, "particularly remote regions". Concern was also expressed for better-measured, real-time data that are readily available. Overall, the sentiment was "We need more data."

Specific data mentioned for future hydrological modelling included meteorological data (particularly rainfall), topographic data, streamflow data, vegetation data, data on ecosystems, data relating to catchment hydrology and "social and economic data". It is worth noting that several hydrologists noted the difficulty in collecting water-use data for the Canterbury region.

6. **Do you think New Zealand should have a central source of hydrological data/information? (Please briefly elaborate.)**

A majority of respondents felt that New Zealand should have a central source of information. One respondent considered a central source as of "national importance", as it would prevent the occurrence of contradictory data and avoid the problem of scattered and isolated information sources, which "[are] a nightmare when assembling nationwide information". Many called for a web-based database that is freely available to the public, and includes the likes of water-quantity and -quality data. However, there were differences in opinion about the role that a central body should play. Some felt that a national centre should be responsible for collecting, processing and archiving data. Other respondents believed that regional councils should be in charge of their own data, with quality controlled centrally and data available to all. Some respondents noted that data has to be stored in as raw a form as possible to ensure that details are not lost,. Others opined that there should be co-ordinated data ownership to prevent monopolisation by the provider. One respondent who opposed centralized information said that "it is useful but not essential". The main reason against centralized information was that data sets are generally applicable only to specific regions. Questions about accuracy, quality and reliability were also highlighted as reasons against a central source of information.

Some respondents reported that New Zealand already has some freely accessible central information sources such as the former Ministry of Works and Development data repository, the National Hydrometric Database (available at www.edenz.niwa.co.nz), or NIWA's CliFlo database. Criticisms included costs involved with some databases and the availability of only surface water and not groundwater data.

7. **Do you think that New Zealand should have a Central Water Policy? (Please briefly elaborate.)**

The question elicited a greater range of responses than the previous questions. The question was not meant to imply that hydrologists are in a position to decide for society on water policy, and was meant only to gauge opinions of those most familiar with hydrologic sciences. The respondents who were in favour of a central water policy argued for a need to achieve consistent goals and standards across regions, and that a central policy would help solve New Zealand's water quantity and quality problems. They noted that New Zealand is a small and diverse country that requires government to help with issues of national importance, especially environmental matters, and that there is a strong economic and environmental interdependence between regions. Many hydrologists often have multi-regional expertise and they stress that without a central policy there is a lot of duplication of planning procedures.

Some respondents, undecided about the need for a central water policy, pointed out that consultation with stakeholders is a required but difficult process for an effective central policy. They emphasised that only over-arching policies are needed, finer details and implementation could be left to regional councils. Such policies could include specify that "all regions need to have a water plan" and consider national views on lakes or rivers, while leaving the details to the regional authorities.

Many hydrologists who were against a central policy argued that a central water policy could not take into account regional differences ("there is no one-size-fits-all policy"), which would negatively affect smaller regions. For example, the West Coast faces problems more with

flood management than water allocation, a difference which may be ignored by a central policy. One respondent argued that a central policy would be no more than “a warm and fuzzy declaration to look after New Zealand’s water”.

Discussion

Survey limitations and insights

Several limitations became apparent with this research, including coding and interpreting text responses (Rodeghier, 1996), and the potential for ambiguity in the identified factors (Hair et al, 2003). Despite the testing of the questionnaire by experts, the selected factors might still yet be unrepresentative of hydrological problems and issues.

The low completion rate was probably due to the amount of time required to complete the questionnaire (20 minutes), and website failure, which was reported by seven respondents. Furthermore, the mailing list included several non-hydrologists, such as ecologists, and overseas members of the society, who were unable to be isolated from the target population. We did not attempt to provide incentives to increase responses. It is possible that some other (more expensive and intrusive) method may have been more effective in obtaining answers to the posed questions.

Information needs

Respondents listed four types of data as both lacking and important:

- representative models,
- data for more advanced models (e.g., models requiring the use of GIS technology),

- information on water interactions (e.g., groundwater–surface water interactions), and
- information on sustainability of water resources.

These factors can be considered major concerns to New Zealand hydrologists.

Climate change data were identified as lacking but not important, perhaps because of uncertainty about the effects of climate change.

The factors selected for the survey included a number of broader contextual issues (eg, Treaty issues, macroeconomic factors) related to water. These were selected to help assess the extent to which hydrologists feel limited by progress in non-hydrological issues which are of increasing importance to hydrologists. These results indicate that a lack of information is not limiting the ability for a multi-disciplinary management of water.

Seven factors were seen as important but not lacking (good monitoring devices, high measurement accuracy, adequate research budgets, weather-pattern and climatological data, information on uses of the land, information on characteristics of the land, and identification and awareness of the ecosystem dependent on water). More factors were identified as important than lacking, which indicates the current strength of New Zealand hydrology.

Managerial and policy implications

The findings provide an insight into the opinions of a group of New Zealand hydrologists regarding New Zealand's water management and allocation problems. This group identified four factors as lacking and important. These factors need to be addressed to meet New

Zealand's need for better water policy. The findings also indicate that government may need to play a central role in providing access to high quality data, while also guiding water policies which have national consequences. Future research should explore how to provide the data that hydrologists need.

Acknowledgements

We thank the many hydrologists who took the time to complete the on-line survey. We also thank Janet Bray and the Journal's referees for help with improving the text.

References

Baca, E. 1999: On the misuse of the simplest transport model. *Ground Water, 37(4)*, 483.

Brace, I. 2004: *Questionnaire design*. London: Kogan Page.

CareerServices 2008: http://www.careers.govt.nz/default.aspx?id0=1060103&id1=J28113, accessed 29 May 2008.

Carver, R. H., and Nash, J. G. 2006: *Doing data analysis with SPSS Version 14*. Pacific Grove: Duxbury.

Davies-Colley, R., and Wilcock, B. 2004: Water quality and chemistry in running waters. In J. Harding, M. P. Mosley, C. Pearson and B. Sorrell (eds.), *Freshwaters of New Zealand*, (pp. 11.1–11.18). Christchurch: New Zealand Hydrological Society and New Zealand Limnological Society.

Environment Waikato. 2008. The condition of rural water and soil in the Waikato region - risks and opportunities. http://www.ew.govt.nz/Audiences/For-farmers/The-condition-of-rural-water-and-soil-in-the-Waikato-region---risks-and-opportunities/ accessed 12 Nov 2008.

Gray, P. 2002: *Psychology* (4 ed.). New York: Worth Publishers.

Hair, J. F. J., Bush, R. P., and Ortinau, D. J. 2003: *Marketing research: within a changing environment* (2 ed.). New York: McGraw-Hill/Irwin.

Ibbitt, R. P., and McKerchar, A. I. 1992. Streamflow and the use of models. In M. P. Mosley (Ed.), Waters of New Zealand (pp. 117-134). Wellington: New Zealand Hydrological Society.

Lewin, C. 2005: Elementary quantitative methods. In B. Somekh and C. Lewin (eds.), *Research methods in the social sciences* (pp. 215–225). London: Sage Publications.

Lowry, T. S., Bright, J. C., Close, M. E., Robb, C. A., White, P. A., Cameron, S. G. 2003. Management gaps analysis: a case study of groundwater resource management in New Zealand. *International Journal of Water Resources Development*. 19 (4), pp. 579-592

Painter, D. 2004: Managing water-related risks. In J. Harding, M. P. Mosley, C. Pearson and B. Sorrell (eds.), *Freshwaters of New Zealand* (pp. 45.1–45.16). Christchurch: New Zealand Hydrological Society and New Zealand Limnological Society.

Paterson, A. M., Cumming, B. F., Smol, J. P., Blais, J. M., and France, R. L. 1998: Assessment of the effects of logging, forest fires and drought on lakes in northwestern Ontario: a 30-year paleolimnological perspective. *Canadian Journal of Forest Research*, 28(10), pp. 1546–1556.

Punch, K. F. 2003: *Survey research: the basics*. London: Sage Publications.

Richmond, C., Froude, V., Fenemor, A., and Zuur, B. 2004: Management and conservation of natural waters. In J. Harding, M. P. Mosley, C. Pearson and B. Sorrell (eds.), *Freshwaters of*

New Zealand (pp. 44.1–44.20). Christchurch: New Zealand Hydrological Society and New Zealand Limnological Society.

Rodeghier, M. 1996: *Surveys with confidence: a practical guide to survey research using SPSS*. Chicago: SPSS Inc.

Salinger, J., Gray, W., Mullan, B., and Wratt, D. 2004: Atmospheric circulation and precipitation. In J. Harding, M. P. Mosley, C. Pearson and B. Sorrell (eds.), *Freshwaters of New Zealand* (pp. 2.1–2.18). Christchurch: New Zealand Hydrological Society and New Zealand Limnological Society.

Saunders, M., Lewis, P., and Thornhill, A. 2007: *Research methods for business students* (4 ed.). Harlow: Pearson Education Limited.

Taylor, S. J., and Bogdan, R. 1998: *Introduction to qualitative research methods* (3 ed.). New York: Wiley.

White, P. A., and Rosen, M. R. 2001: Introduction. In M. R. Rosen and P. A. White (eds.), *Groundwaters of New Zealand* (pp. 1–3). Wellington: New Zealand Hydrological Society.

Woods, R., and Howard-Williams, C. 2004: Advances in freshwater sciences and management. In J. Harding, M. P. Mosley, C. Pearson and B. Sorrell (eds.), *Freshwaters of New Zealand* (pp. 1.1–1.20). Christchurch: New Zealand Hydrological Society and New Zealand Limnological Society.

Table 1 – Survey questions

1. Please indicate the extent to which you lack information on the following factors as relevant to your work (0 = low lack of information, 5 = high lack of information).

2. How important do you feel the following factors are to your work towards water management? (0 = low importance, 6 = extremely high importance)

3. What kind of models do you currently use?

4. Do you find anything lacking in these models?

5. What sort of data would you need for the models that you would prefer to use in the future?

6. Do you think New Zealand should have a central source of hydrological data/information?

7. Do you think that New Zealand should have a Central Water Policy?

Table 2 – Employer type of survey respondents (n=78). Respondents could select more than one employer.

Employer Type	%
Crown Research Institute	23.1
University	17.9
Private firm	17.9
Self-employed (Consultancy)	12.8
Regional Council	9.0
Territorial Authority (District/City Council)	9.0
Unitary Authority	6.4
Government ministry or other government agency	5.1
Community interest group	1.3
Other	5.1

Table 3 – Region of residence reported by survey respondents (n=74). No representation of Marlborough.

Region	%
Canterbury	39.2
Waikato	14.9
Otago	9.5
Wellington	8.1
Auckland	6.8
Tasman/Nelson	5.4
West Coast	4.1
Bay of Plenty	2.7
Manawatu-Wanganui	2.7
Gisborne	1.4
Hawke’s Bay	1.4
Northland	1.4
Southland	1.4
Taranaki	1.4

Table 4 – Main issues by region. Gisborne, Hawke's Bay, Northland, Southland and Taranaki are omitted, as the data insufficient to identify main issues.

Main issue	Auckland	Bay of Plenty	Canterbury	Manawatu-Wanganui	Otago	Tasman /Nelson	Waikato	Wellington	West Coast
Water quality	x		x	x	x		x	x	x
Water allocation	x		x		x	x		x	
Water management	x			x		x			
Water quantity	x				x	x	x	x	x
Water rights	x								
Water efficiency	x				x			x	
Modelling		x	x					x	x
Measurement		x	x				x		x
Water management			x		x				
Agricultural /industrial use of water							x		
Climate change								x	x
Lack of research funding								x	x

Table 5 – Analysis of results for question "Indicate the extent to which you lack information on the following factors as relevant to your work." 0 = low lack of information, 5 = high lack of information (n = 60). Sorted by mean score. A 'significant lack' is defined as a greater than 5% probability that the mean score is above 2.5.

Factor	Mean	t-value, df=59	Prob. mean > 2.5	Signif-icant lack?
Information on interaction of water with other variables (e.g., groundwater-surface water interactions)	2.750	1.692	0.096	Yes
Representative models	2.350	-0.830	0.410	Yes
Information on sustainability of water resources	2.333	-0.980	0.331	Yes
Data for more advanced models (e.g., models requiring the use of GIS technology)	2.200	-1.639	0.107	Yes
Climate change data	2.167	-1.731	0.089	Yes
Data on uses of the land (e.g., agriculture, conversion rates, fertiliser and contaminant uses)	1.967	-3.098	0.003	No
Good monitoring devices	1.917	-3.569	0.001	No
Data on the effects of pollution (e.g., leaching rates)	1.883	-3.035	0.004	No
Identification and awareness of the ecosystem dependent on water	1.883	-3.347	0.001	No
Weather-pattern and climatological data	1.850	-3.954	0.000	No
Adequate research budgets	1.833	-2.996	0.004	No
Information on water efficiency (e.g., leakages and wastages)	1.767	-4.021	0.000	No
High measurement accuracy	1.700	-4.769	0.000	No
Information on characteristics of the land (e.g., geological structures)	1.683	-4.934	0.000	No
Data on demand for water by human users	1.617	-4.755	0.000	No
Water quality indicator data (e.g., on eutrophication levels, saltwater intrusion)	1.550	-5.142	0.000	No
Information on water-related hazards (e.g., floods)	1.550	-5.369	0.000	No
Information on interests of local community groups	1.483	-6.273	0.000	No
An established system for and enforcement of water rights	1.417	-5.775	0.000	No
Adequate control of research budget	1.367	-5.383	0.000	No
Information on government policies for a market for water	1.350	-5.284	0.000	No
Information on the socio-cultural contexts surrounding water (e.g., recreational uses of water in the region)	1.200	-9.078	0.000	No
Information on Treaty of Waitangi regulations	0.883	-10.243	0.000	No
Data on macroeconomic variables (e.g., interest rates, inflation)	0.450	-13.913	0.000	No

Table 6 – Analyis of results for question "How important do you feel the following factors are to your work towards water management?" 0 = low importance, 6 = extremely high importance (n = 65). Sorted by mean. A 'Significant Importance' is defined as a greater than 5% probability that the mean score is greater than 3.

Factor	Mean	t-value, df=64	Prob. mean > 3	Signifi-cant import-ance?
Good monitoring devices	4.123	8.984	0	**Yes**
High measurement accuracy	3.569	3.829	0	**Yes**
Sustainability of water resources	3.538	3.279	0.002	**Yes**
Interaction of water with other variables (e.g., groundwater-surface water interactions)	3.492	3.38	0.001	**Yes**
Uses of the land (e.g., agriculture, conversion rates, fertiliser and contaminant uses)	3.169	1.045	0.3	**Yes**
Identification and awareness of the ecosystem dependent on water	3.077	0.415	0.679	**Yes**
Representative models	3.046	0.241	0.811	**Yes**
Characteristics of the land (e.g., geological structures)	2.923	-0.399	0.691	**Yes**
Larger research budgets	2.815	-0.903	0.37	**Yes**
Availability of data for more advanced models (e.g., models requiring the use of GIS technology)	2.754	-1.075	0.286	**Yes**
Weather patterns and climatological data	2.738	-1.284	0.204	**Yes**
Demand for water by human users	2.569	-2.366	0.021	No
Interests of local community groups	2.569	-2.496	0.015	No
An established system and enforcement of water rights	2.492	-2.495	0.015	No
Water quality indicators (e.g., Eutrophication levels, saltwater intrusion)	2.4	-2.825	0.006	No
Information on water-related hazards (e.g., floods)	2.354	-3.049	0.003	No
Measuring the effects of pollution (e.g., leaching rates)	2.277	-3.429	0.001	No
Climate change data	2.154	-4.51	0	No
The socio-cultural contexts surrounding water (e.g., recreational uses of water in the region)	2.154	-4.04	0	No
More control of your research budget	2.031	-4.105	0	No
Water efficiency (e.g., leakages and wastages)	2	-5.006	0	No
Government policies for a market for water	1.492	-6.582	0	No
Treaty of Waitangi considerations	1.262	-8.849	0	No
Macroeconomic Variables (e.g., interest rates, inflation)	0.4	-16.166	0	No

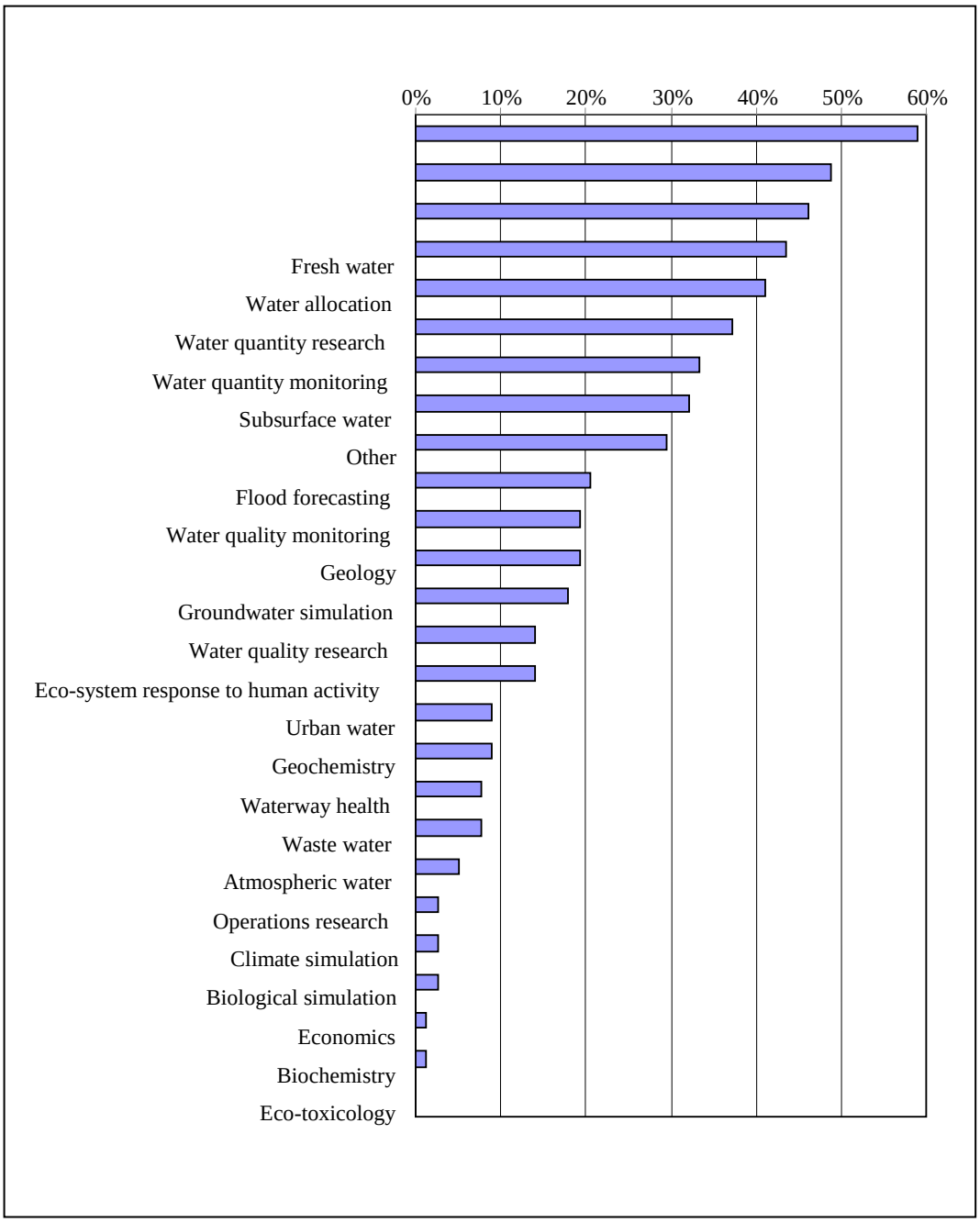

Figure 1 – Areas of expertise of survey respondents (n=78). Respondents were allowed to select multiple areas of expertise.